Offshore Technology Roadmap for the Ultra Deepwater Gulf of Mexico

U.S. Department of Energy

November 2000

Foreward

The goals of enhancing America's energy security and providing diverse energy technologies for the future come together in "Offshore Technology Roadmap for the Ultra-Deepwater Gulf of Mexico." It represents an uniquely American solution to current international energy challenges. In "Powering the New Economy" the Administration identified meeting these challenges as essential to the continued economic growth of the new Information Age and its hunger for energy supply, energy reliability and energy infrastructure.

The U.S. taxpayers own vast untapped oil and gas resources underlying public lands and waters in the deepwater of the Western Gulf of Mexico; the Department of Energy's national labs posses technologies and the ability to develop solutions that can address key technology gaps; and the private investment community has the risk management tools necessary for large cutting-edge deployments. Like the Minerals Management Service's program of deepwater royalty relief, investment today will pay off in reducing America's dependence on foreign oil, and the application of new, safe and sustainable production processes. Simply bringing these national assets together is not enough to bring costs down and environmental protections up. Meeting the Nation's growing demand for energy through safe and sustainable deepwater energy development requires a deliberate, coordinated, and well-financed effort - it requires a detailed roadmap.

This report, and the roadmapping exercise that produced it, is the result of a series of transparent workshops held across the nation. A wealth of information was produced to compliment internal sources like the Energy Information Administration. The active participation of the Department's stakeholders is greatly appreciated. Walter Rosenbusch, Director of the Minerals Management Service (MMS) deserves special recognition. His partnership, participation and input were instrumental to the success of this effort.

I also would like to thank my friend Governor Mark White for his participation and support of this effort. In addition, I thank the following workshop chairs and moderators for their participation and contribution to the roadmapping efforts: Mary Jane Wilson, WZI, Inc.; Ron Oligney, Dr. Michael Economides, and Jim Longbottom, University of Houston; John Vasselli, Houston Advanced Research Center; and Art Schroeder, Energy Valley.

This report, however, does not represent the end of such long-range planning by the Department, its national labs, and its stakeholders. Rather it is a roadmap for accelerating the journey into the ultra-deepwater Western Gulf of Mexico. The development of new technologies and commercialization paths, discoveries by marine biologists, and the fluctuations of international markets will continue to be important influences.

With that in mind, let the journey begin.

Emil Peña

Deputy Assistant Secretary
for Natural Gas and Petroleum Technology

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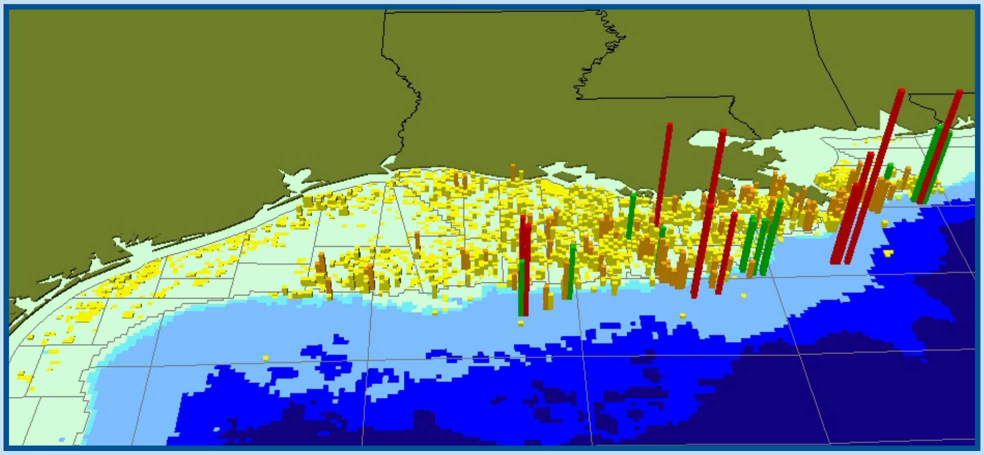
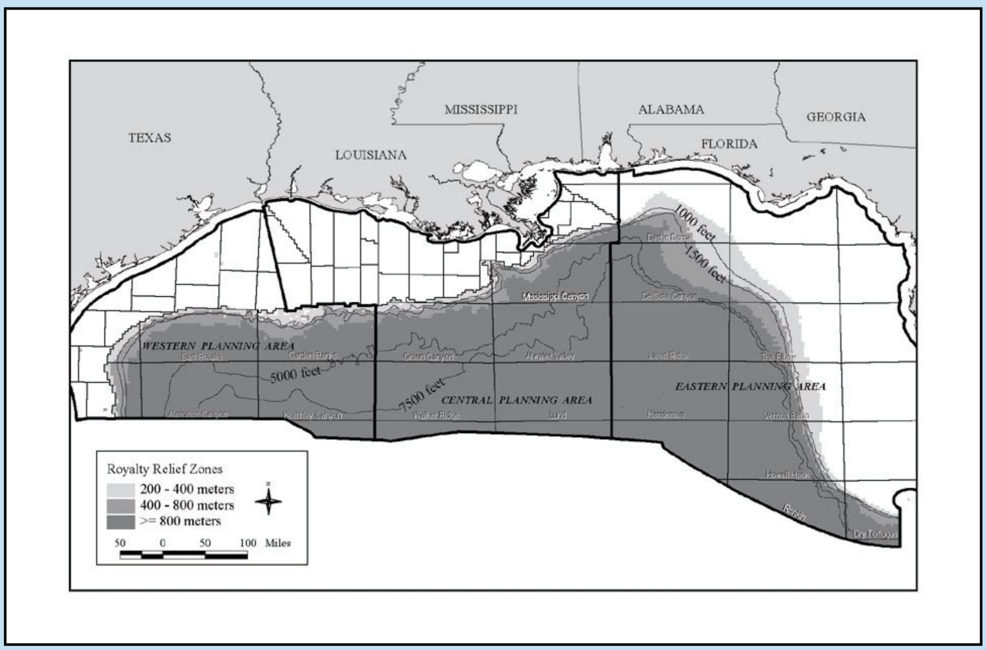


Maximum historical oil production rates for Gulf of Mexico wells. Taller bars indicate higher production rates. The data show numerous deepwater oil wells produced at significantly higher rates than ever seen in the Gulf of Mexico.



The Gulf of Mexico OCS is divided into Western, Central, and Eastern Planning Areas. The above exhibit shows the lease tracts, water depths, and Deepwater Royalty Relief Zones.

Source: Deepwater Gulf of Mexico: America's Emerging Frontier; Minerals Management Service, OCS Report MMS 2000-022, April 2000.

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The Purpose

An effort to enhance the Nation's energy security through research, development and commercialization of technologies, and to explore the order of magnitude of funding needed for accelerated ultra-deepwater offshore energy development.

The Offshore Technology Roadmapping (OSTR) is a major initiative to unite natural gas and oil producers, service companies, national laboratories, investors, non-governmental organizations, consumers/end-users, and various federal agencies in an effort to enhance the Nation's energy security through research, development and commercialization of technologies, and to explore the order of magnitude of funding needed for accelerated ultra-deepwater offshore energy development. Investment in new ultra-deepwater technology development is key to increasing energy security while also maintaining proper environmental stewardship. The U.S. Department of Energy's goal is to develop a roadmap of the actions that will make the energy resources of the U.S. Gulf of Mexico (GOM) ultra-deepwater a more fully contributing element of our Nation's energy security.

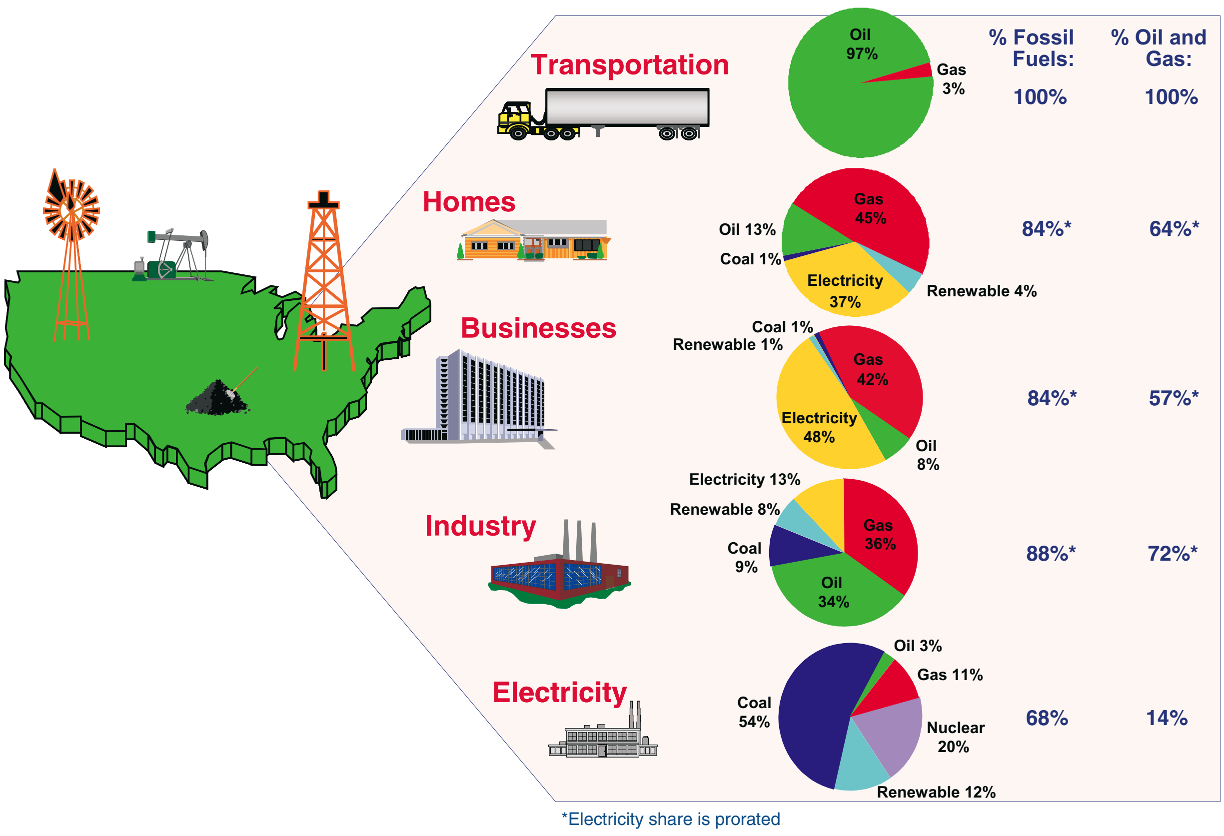
The Issue

The U.S. taxpayers own vast untapped oil and gas resources underlying public lands and waters in areas such as the Gulf of Mexico. The ultra-deepwater GOM holds enormous potential to help meet the Nation's growing demand for energy. Many experts believe that the deepwater reservoirs of the Gulf of Mexico have the potential to provide as much oil and natural gas as the North Slope of Alaska. Development efforts of this resource-rich area, although rapid, are not proceeding fast enough to meet the economy's growing demand or to slow the increasing reliance on imported supplies of oil. Projections by the Energy Information Administration (EIA) and others indicate that, in 2015, the U.S. demand for oil and natural gas will reach 25 million barrels/day and 30 trillion cubic feet (Tcf), respectively. Compared to U.S. consumption rates in 1999, this represents a 23 percent increase in demand for oil and more than 39 percent increase in natural gas demand. The U.S. has been increasing its reliance on oil and natural gas imports to meet this demand. It is imperative that future growth in demand be met in greater part by growth in U.S. production to reverse our Nation's growing dependence on imported energy.

The ultra-deepwater Gulf of Mexico (GOM) holds enormous potential to help meet the Nation's growing demand for energy.

The U.S., while an importer of oil, can remain dominant in the global petroleum industry through our collective technologies. The simple fact is that the petroleum industry is one of the key linchpins that drives the U.S. and global economy. Energy is essential to economic growth and critical to world peace and political stability. To understand the criticality of the petroleum industry to the U.S. economy, one must first understand the scale and impact of this industry. It is easy to overlook this fact because the energy industry has become very efficient at delivering product to the market. Only when supply is disrupted does our society take notice of the petroleum business that they take for granted. The accompanying Exhibit 1 illustrates the size of the natural gas and oil use relative to the other energy resources.

Exhibit 1. Our Economy Runs on Fossil Fuels



Reference: Energy Information Administration, Annual Energy Outlook, 2000.

It is also important to understand how our Nation's economy uses energy and where it comes from. Over 80 percent of the energy consumed during the course of any day in the U.S. comes from fossil fuels, and almost 85 percent of that fuel is oil and natural gas.

There are several other important points to be made about the dependence of our Nation's economy on oil and natural gas:

1. In 1998, the U.S. was using over 59 quadrillion British Thermal Units of natural gas- and oil-derived energy annually with about 37 percent from natural gas and 63 percent from oil.

2. The volume of energy that is supplied to the U.S. economy in the form of hydrocarbons cannot be replaced in the near future by any of the alternative fuels that have been developed.

3. Of the oil fraction, about 59 percent is imported and only 41 percent is domestically produced, a fact that leaves the Nation exposed to interruptions in supply and price shocks.

4. Most of the products that we take for granted, such as plastics and synthetic fibers are made from feedstocks of oil and natural gas.

The Challenge

Water depths of greater than 1,300 feet are classified by the Minerals Management Service (MMS) as "deepwater." Water depths of greater than 5,000 feet are classified as "ultra-deepwater." Deepwater production requires specialized technology. Ultra-deepwater requires even more sophisticated breakthrough technologies in order to achieve economically sustainable production. These greater water depths create unique production

. . . greater water depths create unique production challenges.

Glomar Explorer (photo courtesy of Global Marine, Inc.)

challenges compared to conventional offshore methods. Some of the challenges relate to technical and mechanical limitations, while others are associated with the high cost of current technology, and the pristine, yet hostile environment of the ultra-deepwater.

Scientific research and development (R&D) of new technologies that will lower the cost of bringing these new energy supplies to the consumer, while protecting the environment, are needed. Energy supply projections are based in part on the industry's investment in the development and advancement of key essential technologies. The cost to design and implement an ultra-deepwater technology demonstration program is on the order of hundreds of millions of dollars. Therefore, assuring timely development of the Nation's ultra-deepwater resources requires a deliberate, coordinated, and well-financed effort on the part of industry, government, and academia to address the key technological gaps that present a barrier to this development. This effort of proper stewardship of the Nation's energy and financial resources can enhance the Nation's energy security.

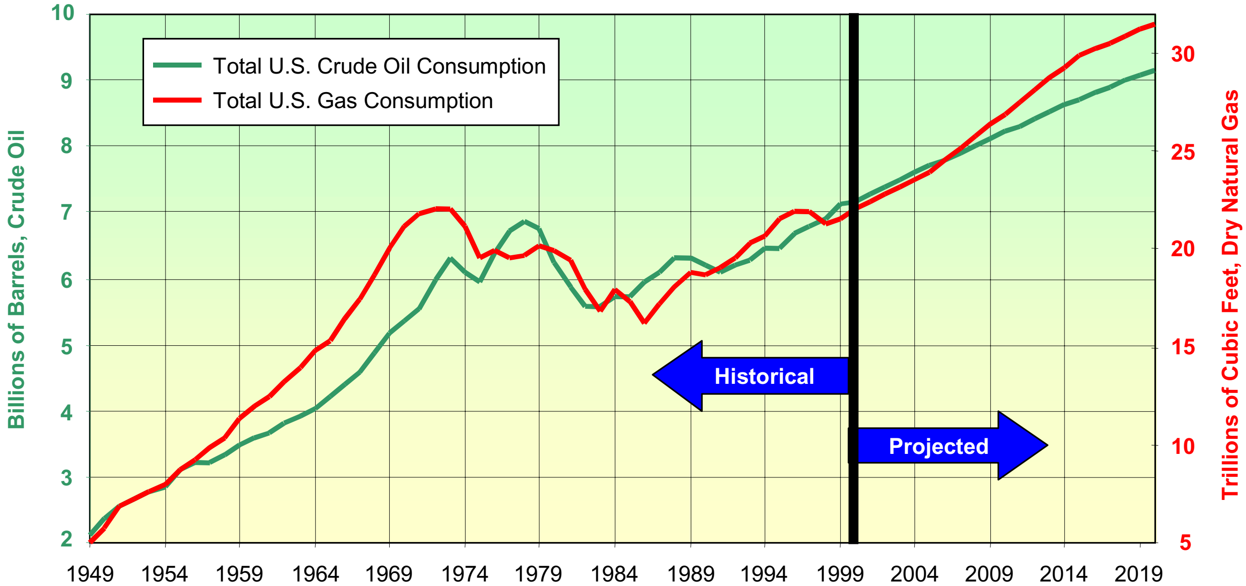
The Situation

Growing Demand: In the first half of the year 2000, the Nation's consumers faced a very tight gasoline market. Domestic crude oil and gasoline inventories were at historically low levels. The demand for natural gas was also at significantly high levels, resulting in natural gas future prices of about $5 per thousand cubic feet (Mcf). As cited in the National Petroleum Council's Natural Gas study (*Meeting the Challenges of the Nation's Growing Natural Gas Demand, December 1999*), domestic gas demand is projected to grow to 29 trillion cubic feet in 2010 and could rise beyond 31 trillion cubic feet in 2015 (see Exhibit 2), and this additional load presents many challenges to suppliers of natural gas. The study further states that this demand will be met by U.S. production, along with increasing volumes from Canada and some liquefied natural gas imports. Of note is the Council's belief that "...an unprecedented and cooperative effort among industry, government, and other stakeholders will be required to develop production from new and existing fields..." Technology and financial requirements are among the top three factors cited by the Council as critical to addressing the anticipated demand from natural gas. This OSTR is the first step in addressing this need in the ultra-deepwater Gulf of Mexico.

Price Volatility: Low oil prices two years ago (see Exhibit 3) created disincentives in the petroleum industry for exploration

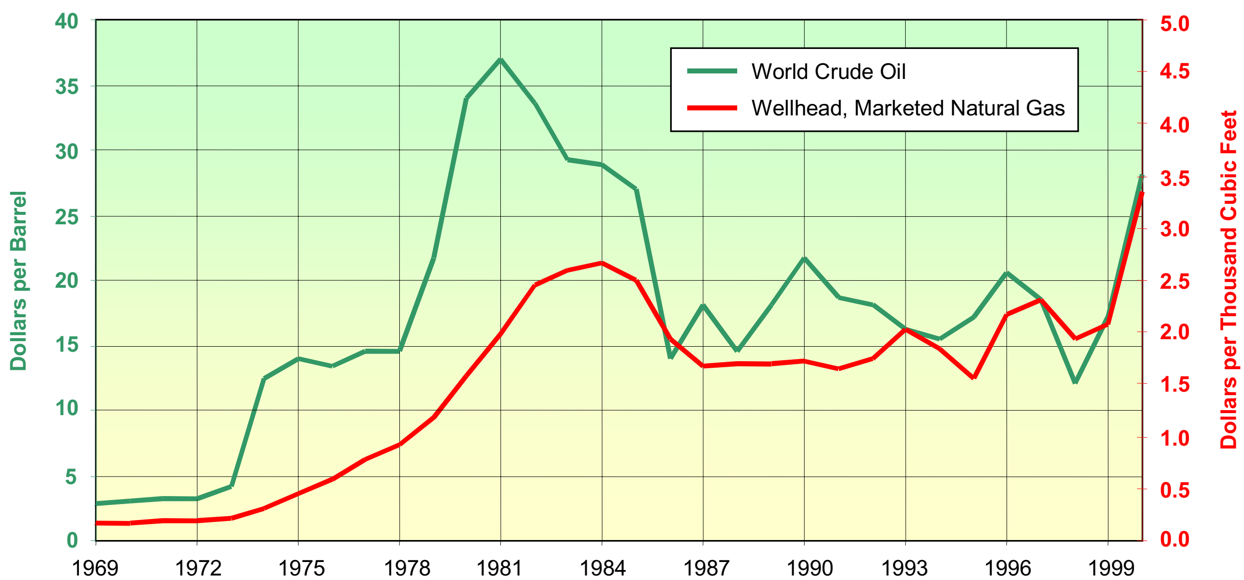
"...an unprecedented and cooperative effort among industry, government, and other stakeholders will be required to develop production from new and existing fields..."

Exhibit 2. U.S. Oil and Gas Consumption (1949–2020)



Source: Energy Information Administration

Exhibit 3. U.S. Oil and Gas Prices

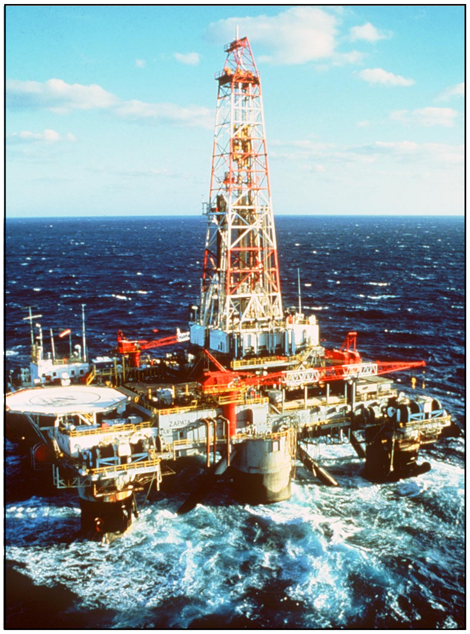


Source: Energy Information Administration

An initiative supported by industry, investors, regulators, and consumers, and has the goal to accelerate development of technologies targeted to increase U.S. ultra-deepwater reserves development is, therefore, in the interest of national security and national economic growth.

and production (E&P) spending. Oil service industry revenues have been impacted severely by reduced and/or deferred E&P projects. The only area that has withstood the pressure of extreme price volatility is the deepwater and ultra-deepwater Gulf of Mexico. This is because most projects in these regions are in early stages of exploration and development and near-term oil prices have little impact on return on investments. In addition, the reserves have been typically large enough to justify development, even when oil prices are lower; and production can be prolific enough to yield fast payback with the help of advanced technologies.

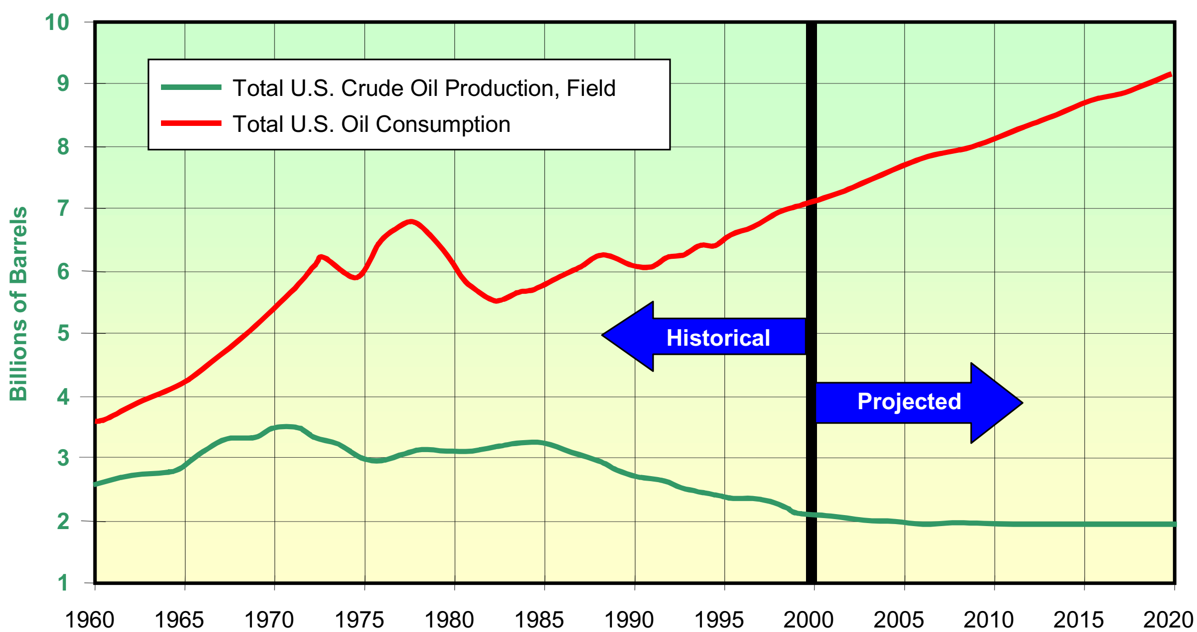
Extreme market volatility can negatively impact several sectors of the economy — both energy consumers and producers. Even as crude oil prices have rebounded, financial markets have remained cautious, money continues to be tight, and reinvestment in the domestic oil industry has not fully materialized. On the other hand, extreme market pressure for natural gas supply has driven the rig count to over 1,000, 80 percent of which is for the drilling of natural gas wells. At present, producing companies are pursuing several options for future investments including deepwater development and overseas partnerships with national oil companies. If the U.S. is to improve its energy supply balance, it is essential that investments be directed toward development of domestic resources, as well as other non-U.S. supply sources. To achieve this goal requires that industry and government work together to remove critical barriers to deepwater investment in the U.S. Accelerated development of deepwater and ultra-deepwater reservoirs has the potential to stabilize energy supplies and reduce U.S. dependence on imported sources. An initiative supported by industry, investors, regulators, and consumers, and has the goal to accelerate development of technologies targeted to increase U.S. ultra-deepwater reserves development is, therefore, in the interest of national security and national economic growth.



The Background

The Energy Information Administration reports that domestic crude oil production declined over the 1986 to 1996 decade from a level of 3.2 billion barrels in 1986 to 2.3 billion barrels in 1998 (See Exhibit 4). Domestic demand continued to rise, however, from 5.9 billion barrels in 1986 to 6.9 billion barrels in 1998. The difference was satisfied by increased imports, which have exceeded domestic production since 1994. Regionally, while relative levels of production from the lower 48 States and Alaska remained about the same, total production fell 26 percent in the Lower 48, and 21 percent in Alaska over the 1985-1996 period. Onshore production fell 30 percent over the period and its share of total production fell by 6 percent while offshore production increased by almost 8 percent. The above statistics in part reflect continuing depletion of the Nation's crude oil resource endowment, but other factors have influenced this trend. The size of new field discoveries is economically important because lifting costs per unit of production fall in response to increasing field size. In general, the largest fields in a new exploration area are among the first to be discovered. Therefore, since the onshore lower 48 States comprise the most intensively explored area on Earth, the remaining undiscovered oil resources occur in mostly small-to medium-sized fields—or in relatively unexplored areas such as the ultra-deepwater Gulf of Mexico.

Exhibit 4. U.S. Crude Oil Production and Consumption (1960–2020)



Source: Energy Information Administration

Deepwater GOM field discovery sizes have been several times larger than the average shallow-water field discoveries.

In its April 2000 report, *Deepwater Gulf of Mexico: America's Emerging Frontier*, the Minerals Management Services states that *The deepwater Gulf of Mexico (GOM) has recently emerged as an important oil and gas province and an integral part of the Nation's oil and gas supply. A major milestone occurred in late 1999 when more oil was produced from the deepwater GOM than from the shallow-water GOM. This trend in increasing deepwater production is expected to continue, along with high levels of exploratory drilling, development activity, pipeline construction, and shore support activities. Deepwater GOM field discovery sizes have been several times larger than the average shallow-water field discoveries. The deepwater fields have also been some of the most highly prolific producers in the GOM.*

In 1999, total GOM oil production reached an estimated 494 million barrels after producing about 300 million barrels per year for much of the decade. The increase has come from the deepwater and was highlighted in late 1999, when oil production from the deepwater portion of the GOM exceeded that of the shallow water for the first time in history. This historic change after 53 years of GOM production has been driven by several major factors that all coalesced in the later 90s. High flow rate wells have driven the economics of projects and have acted as a strong incentive to explore and develop deepwater leases. The use of subsea well completions has also contributed to the economics of deepwater projects.

Deepwater operations are very expensive and often require significant amounts of time between initial exploration and first production. A further constraint is the availability of drilling rigs capable of drilling deepwater wells. These factors are critical to the economic success of deepwater development. There has been a steady increase in deepwater rig activity during this time, and the number of rigs drilling in the deepwater GOM is expected to continue increasing slightly through 2001. However, according to MMS, even with the increased number of deepwater rigs, only a small fraction of the 3,670 active deepwater leases can be drilled before they expire.

Significant increases in drilling capacity are required if deepwater production is to have an impact on the Nation's energy supply in the near future. Exacerbating the tightness of drilling capacity is the competition for drill-rig resources from other deepwater areas including Brazil, West Africa and the Atlantic Margin provinces. As other deepwater areas start to be explored, this competition will become even more acute.

The History

As indicated in Exhibit 5, leasing activity in the deepwater GOM increased steadily in the early 90s and exploded in 1996 because of, in part, the economic incentives introduced in the Deepwater Royalty Relief Act. The boom in deepwater leasing was also enhanced by the evolution of deepwater technology, several large deepwater discoveries, and excellent production rates coming from deepwater fields.

According to data from the Minerals Management Service, at the end of 1999, there were 30 producing fields in the deepwater Gulf of Mexico, up 30 percent in just 12 months and up 88 percent since 1997.

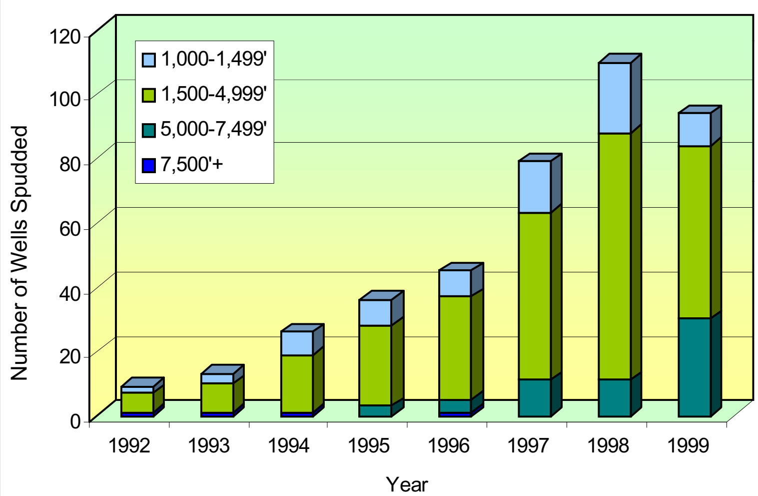
There are approximately 7,600 active leases in the Gulf of Mexico Outer Continental Shelf (OCS), 48 percent of which are in deepwater. Contrast this to approximately 5,600 active Gulf of Mexico leases in 1992, only 27 percent of which were in deepwater. On average, there were 27 rigs drilling in deepwater in 1999, up from only 3 rigs in 1992. Exhibit 6 shows the oil and gas production from offshore GOM. Deepwater oil production rose about 550 percent and deepwater gas production increased almost 800 percent from December 1992 to December 1999.

In 1998, deepwater oil production rose 47 percent over 1997 production, and in 1999 deepwater oil production increased an additional 41 percent over 1998 production. Similarly, deepwater gas production increased 47 percent in 1998, followed by a 51 percent jump in 1999. Although U.S. oil production declined about 410,000 barrels a day from 1994 to 1998, according to MMS, the decline would have been nearly twice as large if the deepwater GOM production had not increased by 321,000 barrels a day.

Deepwater oil production rose about 550 percent and deepwater gas production increased almost 800 percent from December 1992 to December 1999.

All phases of exploration and development moved steadily into deeper waters over the past eight years. This trend was observed by MMS in seismic activity, leasing, exploratory drilling, field

Exhibit 5. U.S. Gulf of Mexico Exploratory Drilling History



Source: Minerals Management Service, April 2000.

The number of wells spudded in the U.S. Gulf of Mexico has increased substantially over the last seven years. The most significant growth of late has occurred in water depths of greater than 5,000 feet.

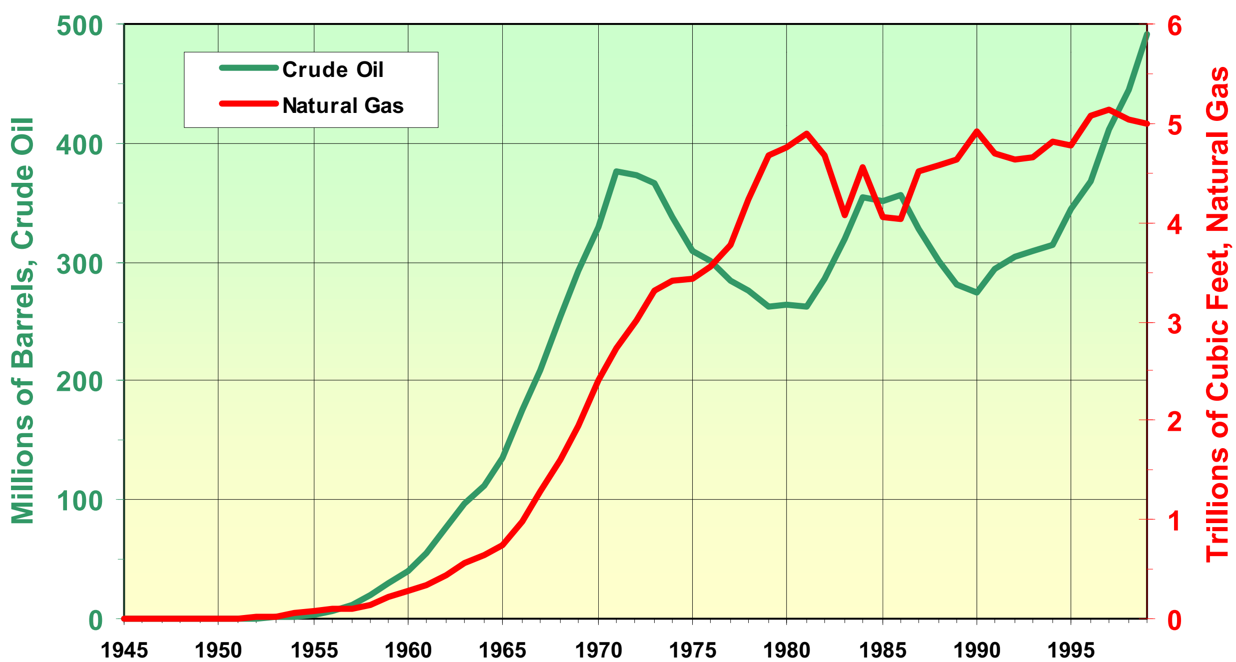
. . . a unique opportunity – the deliberate, focused, cooperative effort of industry and the government to develop the needed technology that will reduce the costs of developing the abundant supply of oil and natural gas from the deepwater GOM.

discoveries, and production. Major oil companies dominated deepwater leasing activity until 1996, when large independents joined the trend. Major oil companies continue to dominate deepwater oil and gas production, but MMS expects production from independents to surge in a few years, when anticipated discoveries on their 1996 through 1999 lease acquisitions begin production.

The Opportunity

The recent unprecedented economic growth experienced by our Nation, fueled by ready supply and availability of energy sets the stage for a unique opportunity— the deliberate, focused cooperative effort of the industry and the government to develop the needed technology that will reduce the costs of developing the abundant supply of oil and natural gas from the deepwater GOM. This OSTR has been the first step in this process by bringing together all the stakeholders in a systematic fashion to identify the technology and other barriers to full development of the ultra-deepwater GOM, and to identify the order of magnitude cost needed in this collaboration.

Exhibit 6. U.S. Oil and Gas Production Offshore Gulf of Mexico



Source: Minerals Management Service

The true full cost of adding incremental production capacity for the Nation or world is the "activation index" or the total investment required to establish access to new oil expressed in dollars per barrel per day of stabilized production. To accelerate production from the ultra-deepwater GOM, the activation index needs to be reduced through technology innovation and other means.

The production of natural gas and oil is also limited in part by the capital available to develop new fields. Production is also limited by the annual decline in existing field production. The opportunity exists to attract more capital to the ultra-deepwater Gulf of Mexico through the use of advanced technology to reduce the "activation index", and through incentives for production. The Nation must invest in the development of better technology that can increase our domestic and, concurrently, global production capacity of natural gas and oil. We need to invest in tomorrow's technology today to bring stability to domestic markets. However, industry funding being committed to research and development of needed technology has deceased. The opportunity exists to change this trend through collaboration.

Research and development partnerships have become increasingly important in recent years. For example, collaborative research and joint industry projects have resulted in the transfer of advanced technologies developed in the U.S. national laboratories to the petroleum industry. Such collaborations have leveraged the resources of industry and government to offset the decrease in R&D funds being committed by the private sector.

The Process

The U.S. Department of Energy facilitated a series of workshops to develop a roadmap to identify producer needs, technology capabilities, investor considerations, possible environmental and safety challenges, government roles, and opportunities for collaboration in the ultra-deepwater GOM. The kickoff meeting was held at the Petroleum Club, Houston, Texas, on July 19, 2000. Exhibit 7 shows the workshops schedule.

Workshop participants included representatives from the producer community, technology suppliers/ service companies, national

Workshop participants included representatives from the producer community, technology suppliers/service companies, national laboratories, federal and state governments, and non-governmental organizations.

laboratories, federal and state governments, and non-governmental organizations (NGOs). This multi-disciplinary approach was used to identify and propose solutions to the challenges associated with deepwater resources development. The kickoff meeting was followed by regional forums focusing on producers, technology entities, investors, NGOs, and federal and state agencies. These interactive, facilitated forums were instrumental in identifying a "roadmap" for addressing major technology needs, environmental and safety challenges, potential government/industry roles, and opportunities for collaboration and investment. The process was inclusive and well attended by all of the stakeholder sectors. Each workshop was focused on addressing a specific question and a set of goals.

Investors Workshop

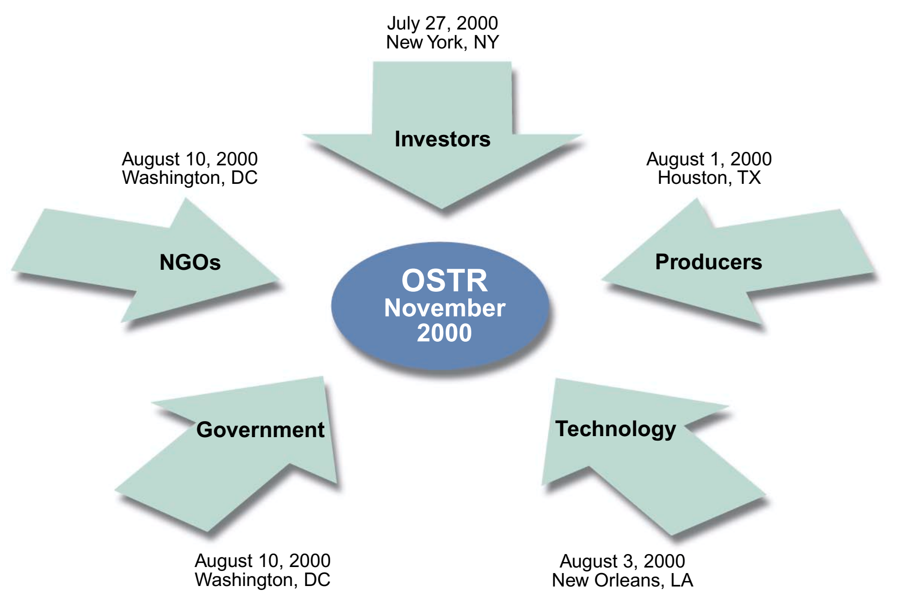
July 27, 2000, The Stock Exchange Club, New York, New York
Facilitated by: Art Schroeder, Energy Valley

Focus: What are the barriers to the investment needed to accelerate technological solutions for ultra-deepwater?

Goals:

- Identify the key factors that producers and technologists must address in order to attract

Exhibit 7. OSTR Workshops



investment for deepwater R&D technology development projects.

- Identify potential strategies or options that could result in greater availability of capital for investment in the development of technology.

- Identify key barriers to attracting investment capital to the energy sector, specifically deepwater technology R&D projects (i.e., financial risk, technical risk, payback time).

Producers Workshop

August 1, 2000, St. Regis Hotel, Houston, Texas
Facilitated by: Ron Oligney, University of Houston.

Focus: What are the technological barriers to the economic and sustainable production of the ultra-deepwater?

Goals:

- Identify technology vision from the perspective of the "major" producing company, large independent, mid-sized independent, and small independent producers.

- Identify the type of partnering relationships possible between the government and its stakeholders.

- Identify key areas of interest for cooperation. Identify successful models of cooperation.

Technology Workshop

August 3, 2000, Wyndham New Orleans at Canal Place, New Orleans, Louisiana
Facilitated by: John Vasselli, Houston Advanced Research Center.

Focus: What are the barriers to developing and implementing technological solutions for the ultra-deepwater?

Goals:

- Identify technology milestones for Fiscal Year (FY) 2001 - 2006 that respond to the priorities identified by the producer community.

- Identify key technology areas requiring the greatest amount of cooperation between stakeholders.

- Identify high cost areas requiring the greatest amount of investment capital.

NGOs Workshop

August 10, 2000, U.S. Department of Energy, Washington, DC
Facilitated by: Mary Jane Wilson, WZI, Inc.

Focus: What are the barriers to developing and implementing technological solutions for the ultra-deepwater?

" . . . evolutionary elements of technology development must be tied together in a way that brings a revolutionary result."

Goals:

- Identify highest priorities and concerns of the NGO community related to the technology associated with deepwater Gulf of Mexico development.
- Identify degree to which the NGO community will cooperate with the technology community in the development of deepwater technology.
- Identify options and strategies for continuing an open dialogue between the NGO community and deepwater Gulf of Mexico developers.

Government Workshop

August 10, 2000, U.S. Department of Energy, Washington, DC
Facilitated by: Emil Peña, Deputy Assistant Secretary, U.S. Department of Energy; Walter Rosenbusch, Director, Minerals Management Service.

It is the integration of individual components of technology into a coherent and well-executed development process that will improve the efficiency of deepwater development.

Focus: What can the federal government do to eliminate barriers and foster the development of technologies in and out of government using our collective strength to be a worldwide leader for sustainable energy development from the ultra-deepwater?

Goals:

- Identify areas of shared mission and appropriate roles.
- Identify key opportunities for cooperation.
- Identify existing and needed mechanisms for maintaining a long-term dialogue on this topic.
- Identify shared measures of success.

The Requirements

Appendix A provides a summary, highlights of comments and inputs provided at the kickoff meeting and the regional workshops. A list of workshop attendees is provided in Appendix B.

During the roadmapping process, stakeholders stated that "evolutionary elements of technology development must be tied together in a way that brings a revolutionary result." A critical point is that no single technology was identified as holding revolutionary potential. It is the integration of individual components of technology into a coherent and well-executed development process that will improve the efficiency of deepwater development to make it competitive with other provinces. It will take major technology advances on multiple fronts in exploration, production, drilling, flow assurance and infrastructure to achieve the revolutionary results required to make deepwater a key component of the national energy supply.

Six major technology themes emerged from the workshops and these reflect the perspectives of the participants. These themes were: Evolutionary and Revolutionary Technologies, New Systems Architecture, First-Time Technology Demonstration, Infrastructure Improvements, Regulatory Innovations, and Improved Communication and Education.

Evolutionary and Revolutionary Technologies: Discrete technology solutions are capable of creating "evolutionary" improvements in energy exploration, development, and production from ultra-deepwater to address the challenge of significantly reducing the activation index of the ultra-deepwater. The environmental challenge of reducing discharge of potentially harmful fluids to near zero (zero emissions/effluents goal) will require "revolutionary" technology solutions. Therefore, the desire to promote a combination of both evolutionary "enhancing" technologies and revolutionary "enabling" technologies should be basic elements of the roadmap structure. Enhancing technologies are those technologies, methods, and processes that have direct impact on specific problems in deepwater exploration, appraisal, and development. These are usually hard technical improvements such as a new logging tool, or a new drilling technique. Enabling technologies, methods, and processes include business performance technologies, communications technology, information technology, human resource management, risk management, and training technologies. These enabling capabilities are not direct technical contributors to success, but help define the infrastructure that supports success in any business venture. As such, they are essential to the success of the deepwater enterprise.

New Systems Architecture: While "technology solutions" typically imply discrete element or subsystem hardware improvements, there is a general consensus that systems level "process improvements" associated with integrated design, real-time management of activities and functions, can have an equal or greater impact on reducing the activation index. Therefore, emphasis on systems engineering

Ultra-deepwater GOM development involves:

- **Evolutionary and Revolutionary Technologies**
- **New Systems Architecture**
- **First Time Technology Demonstration**

Additional aspects include:

- **Infrastructure Improvements**
- **Regulatory Innovations**
- **Communication and Education**

. . . government efforts can serve as a catalyst and facilitator for first-time operational demonstration of enhancing and enabling technologies.

and innovative design processes, which improve the management of uncertainties associated with all phases of energy exploration, appraisal, development, and production, should also be an element of the roadmap structure.

First-Time Technology Demonstration: A clear message delivered by all workshop participants was that the additional risks imposed by the operational first-time use of a technology is a major barrier to accelerating deepwater technology application. Therefore, the roadmap should include ways in which government efforts can serve as a catalyst and facilitator for first-time operational demonstration of enhancing and enabling technologies. By eliminating the enormous risk associated with the first-time application of a new technology, which some workshop participants referred to as the "bleeding edge" of technology, government and other stakeholders would address one of the greatest barriers to the introduction of new technology in deepwater.

. . . that first time use and demonstration of new technologies is a barrier to new technology introduction.

Companies are hesitant to be the first users of new technology in this very risky environment. This is a two-fold problem. First, new technology must be tested more thoroughly than existing technology, which causes a burden on technology developers and first-time users. Second, once the technology is successfully demonstrated, this one data point or "success story" is still viewed as a small success and not yet able to offset the enormous risk associated with the "bleeding edge."

In the past, major companies were willing and able to undertake the risk because of large holdings. Today, producers, with the billion-dollar ultra-deepwater projects in the balance, are not able to assume the additional risk associated with the development and application of new technology not yet proven in this arena. They look to service companies to fill in the R&D gap that was created in the 90s when low oil prices reduced R&D funding. Therefore, new technologies are often not funded or provided with sufficient resources to prove up new technology. No single company can shoulder this burden, and the R&D paradigm has shifted from a time when R&D investment was used to increase a company's competitive advantage to a time when R&D investment brings these same competitors together in joint industry projects. However, this is an option available only to larger firms. Many smaller companies are in a position where they are technologically disadvantaged because of lack of R&D funds especially during times of extreme market volatility.

In addition to the key technology themes listed above, several important aspects associated with the development of the deepwater GOM were discussed at length and deserve mention here as well as recognition in the roadmap process. While these themes are not directly related to technology solution they do represent critical issues and opportunities that are key dimensions of the overall strategy for developing energy resources in the GOM. These themes are:

Infrastructure Improvements: While much of the emphasis was placed on exploration, appraisal, development, and production technologies, there was a clear expression of concerns by workshop participants that not all critical issues were "high-tech" in nature. For new energy to get to the market, the energy and the people who produce that energy must get to shore safely and efficiently. A wide range of challenges, from roads, power, and emergency response to telecommunications, land-based storage and transport, must all be in place to handle the anticipated increase in ultra-deepwater production. While the emphasis of this Roadmap development is on technology, these infrastructure issues must not be neglected.

Regulatory Innovations: A theme that surfaced repeatedly during the workshops was the belief by industry that government policy can affect investment. They believed that one of the best ways to increase investment and accelerate technology innovation in the ultra-deepwater GOM is through regulatory innovation by government toward a position that promotes greater investment. Industry participants believed that government policy innovation could increase the region's economic competitiveness and have a significant positive impact upon the ability of the ultra-deepwater GOM region to attract the needed investment as compared to that of regions outside the U.S. This fact should be acknowledged and an internal government dialogue established to consider the full range of ways that the federal government could best serve to be a catalyst and facilitator for deepwater development. The growing coordination between the Department of Energy and the Minerals Management Service is an example of this important dialogue. It is essential that government provide incentives for

large independents, smaller operators, and service companies who do not have technology development budgets, to engage in this roadmapping process and commit funding and resources to ultra-deepwater. These incentives should be designed to expand the technology development base of the ultra-deepwater industry so that all stakeholders in the process will participate in the program.

Communication and Education: Apart from the specific initiatives and technology recommendations, the participants felt strongly that the open forum dialogue between the varied stakeholders at the workshops was beneficial and innovative in its own right. Strong interest exists to continue such discussions between and within industry, government, academia and non-government organizations. Perhaps of even greater importance is the need to educate the public regarding the strategic importance of domestic energy production to national security. Such education can have broad impact, ranging from encouraging a larger number of students to enter into an energy-related career, to promoting national awareness regarding the cost-benefit-risk tradeoffs associated with the U.S. domestic energy strategy. Within this strategy, the critical role that ultra-deepwater GOM energy production will play in the future economic security of the U.S. must be effectively communicated. Both the energy industry and government must be more proactive in educating the public as to the critical importance and value of the energy industry to the U.S.

One significant and potentially devastating risk to the success of deepwater GOM development is a critical shortage of expertise in several critical skills sets. The petroleum industry is an aging industry with a declining demographic profile. Over the next 10 years, nearly half of the technology and business leaders in ultra-deepwater will retire. At present, the industry is not able to attract top technical specialists due to the competition from other, more lucrative and stable industries. It is essential that industry work closely with government and academic institutions to create opportunities for the brightest and best young minds to enter petroleum disciplines. If current trends in enrollments in key geoscience and engineering disciplines are not reversed in the next few years, the industry will not have the skills needed to execute the number of ultra-deepwater developments needed to make the GOM a contributing element of the Nation's energy security.

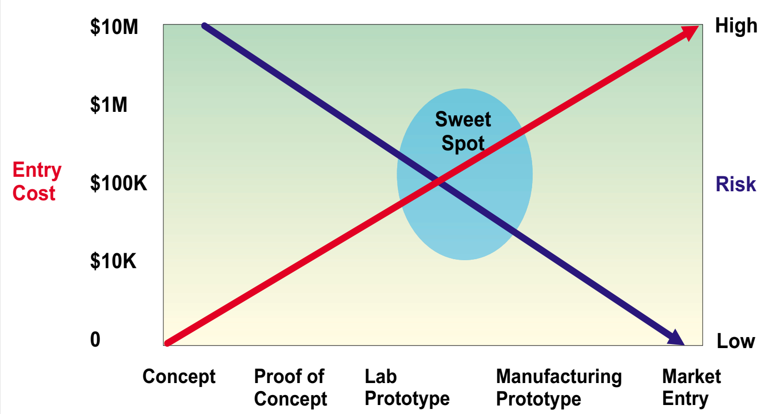
This situation is further exacerbated by the fact that the investment community has not seen sufficient financial returns in the oil and gas industry commensurate with the risks of new technology development. Private investment will remain limited until technologies have a reduced risk profile and more defined market acceptance. From a "risk mix" point of view, investors are interested in technologies that have very near-term applications and that can be licensed to other industries for quicker cash flow and reinvestment. Exhibits 8 and 9 "Preferred Entry Target" and "Preferred Mix of Risk," show the "sweet spots" where investors would be interested in funding technology commercialization. There seems to be a general consensus, particularly by non-industry investors, that outside these "sweet spots," it would be very difficult to attract capital. In particular, the entry cost diagram reveals that investments ranging from $10,000 to about $5 million are in the sweet spot. The cost to design and implement an ultra-deepwater technology demonstration program is on the order of hundreds of millions of dollars. This high cost prevents many deepwater operators from making the necessary investments in new technology that is essential to success. These large investments will require a collaborative approach involving operators, service companies, government, and academia.

However, recent positive developments indicate that the industry could be in the phase of the cycle where selected technology investments might provide a return attractive enough to warrant pursuit. Specifically: (1) energy prices have risen to a level that appear to have enough stability to provide a return; (2) stock prices have risen to the level where it is no longer attractive to "drill on the street" and producers will need to physically drill to replace reserves; (3) many producers and service companies have either severely reduced or eliminated their R&D departments or have shifted focus to rapid adoption and application of technology; and (4) technology was viewed by some as a differentiator that could provide superior returns.

Private investment will remain limited until technologies have a reduced risk profile and defined market acceptance.

Outside the "sweet spot," it is difficult to attract investor capital.

Exhibit 8. Preferred Entry Target



Source: Energy Valley, July 2000.

A technology progresses through a series of stages or phases on its way from concept to commercialization. With passage through each successive phase, the risk associated with the technology is reduced considerably. Conversely, the cost to acquire the technology rises significantly. The risk factor and cost factor scales on the above graph are logarithmic, and astute investors consider the intersection of these two factors to be the optimum relationship between risk and cost thereby referred to as the "sweet spot."

. . . 50 to 80 percent of the potential reduction in the "activation index" lies in the business process of integrating technologies together rather than applying individual technologies themselves.

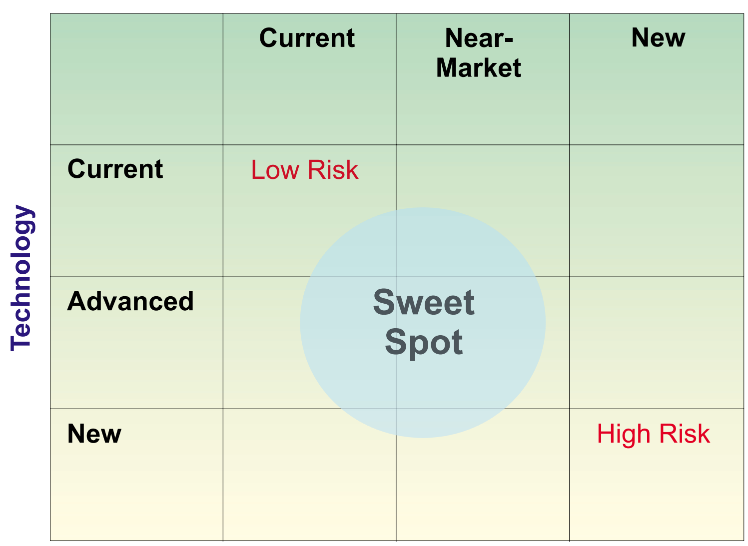
The Strategy

The clear and deliberate consensus of producers, service companies and deepwater technologists is that 50 to 80 percent of the potential reduction in the activation index lies in the business process of integrating technologies together rather than applying individual technologies themselves. The processes that challenge deepwater offshore development can be met through the collaborative efforts described in this roadmap. The keys to affecting the process are:

- Facilitating the development of enhancing technologies that will individually contribute to the success of deepwater by addressing key technical gaps.
- Creating a new and robust deepwater systems design model similar to the high-intensity design concepts used in other industries that incorporate individual enhancing technologies into an integrated whole. This synergism between components would result in greater cost-benefit to producers and ultimately to energy consumers.
- Facilitating the development of enabling technologies that will be essential to the success of deepwater development, including business processes, communication, education, technical training, risk management, and regulatory innovation.

The goal of the new system design model would be to assure that no single node or component failure will be able to cause the whole system to fail. The model will provide a mechanism for incorporating environmental research and protection. The model itself, like the Internet, becomes the rallying point that will invigorate ongoing efforts ranging from DeepStar, to the Natural Gas and Oil Technology Partnership, to Global

Exhibit 9. Preferred Mix of Risk



Reference: Energy Valley, July 2000.

Investors like to be on the leading edge of high growth markets using advanced, but proven technology. If they target markets that are too immature or distant, sales trickle and the Earnings Before Income Taxes, are addressed with technology that is too new, then customer acceptance can be slow and/or costs can be unpredictably high. This is sometimes referred to as being on the "bleeding edge."

Petroleum Research Institute (GPRI), to individual company technology centers, independent research entities such as Houston Advanced Research Center (HARC), and the consuming public. The participants suggested that the incentives necessary to accelerate use of advanced technology could come in various forms such as targeted royalty relief, R&D tax credits, and matching research dollars.

The roadmapping workshop participants concluded that the OSTR initiative should focus on:

- Support for development of new enhancing technologies that will address the technology gaps for deepwater development;
- Support for first time demonstration of new enhancing technologies;
- Support for enabling technologies that will assure a stable infrastructure for the implementation of the deepwater systems design model; and
- Support for the development of a deepwater systems design model that will integrate all of the enhancing technologies into a high-intensity-design system that is facilitated by the enabling technologies.

Whether the new systems design model produces "riserless drilling" or "seafloor drilling" or other advanced technologies, inherent in the design must be that it: (1) reduces the "activation index" sufficiently such that ultra-deepwater competes favorably with foreign sources of hydrocarbons; (2) addresses the ultra-deepwater rig availability that would result from a massive swing in activities to the ultra-deepwater; and (3) improves environmental performance and protection toward the goal of zero emissions and/or effluents.

. . . goal could be achieved through a combination of options and/or incentives that will cause private enterprise and market forces to support needed activities.

The Roadmap

The goal of the Offshore Technology Roadmap is achieving significant accelerated growth in production from the GOM in order to enhance national energy security, and stabilize supplies of needed energy. This goal could be achieved through a combination of

options and/or incentives that will cause private enterprise and market forces to support the needed activities. These incentives will provide the boost needed to overcome the "bleeding edge," – the risk associated with first-time use of technology. As conveyed by the stakeholders participating in the roadmapping workshops, these incentives will need to support two tracks. One track could be tax or royalty incentives to producers to accelerate deepwater and ultra-deepwater production above and beyond a forecast baseline that is derived from a scenario without incentives. This baseline will need to be sufficiently challenging to encourage the use of new technologies in order to achieve maximum benefit from the incentive. The other track could support technology and system integration development and deployment such that new technologies are less risky and reasonably proven (successful first demonstration in an offshore environment) prior to full commercial use in ultra-deepwater projects.

The financial incentives track includes concepts that need further study. Examples include:

The goal of this roadmap initiative is to provide opportunities for new and better ideas to continually develop, rather than prescribe a specific path for technology investments.

- New tax incentives to foster cost-sharing on each project from a wide range of companies, especially those which, traditionally, have not been able to afford expenditures on technology development.

- Tax credits against ultra-deepwater production revenue so that costs can be recovered as new production is brought on line. This will not only inspire operators to invest in technology development, but it will encourage them to bring reserves on line rapidly in order to take advantage of the tax credit.

- Credits applicable only to fields in the U.S. ultra-deepwater that are brought on line after a given project is funded. This will encourage new field development at a greater rate.

- Tax incentives that will offset the investment risk faced by service companies and other technology developers.

The technology development track focuses on system integration. Implicit in defining a new system design model is an appreciation of the technology and subsystem components to be incorporated in the model. Table 1A identifies the systems and integration that need to take place in order to achieve an order of magnitude change in the rate of production growth in the ultra-deepwater U.S. GOM. These systems are shown with a sample time line for achieving development in a six-year horizon.

The goal of this roadmap initiative is to provide opportunities for new and better ideas to continually develop, rather than prescribe a specific path for technology investments.

The new technologies required to achieve the new system architecture are listed in Table 1B. The symbols in the technology table are also shown in the systems table to cross reference the technologies with the systems in which they are used. The list of systems and technologies is quite comprehensive but not prescriptive. This is deliberate.

Brief descriptions of primary categories listed in Table 1A follow:

High Intensity Design applies computer technology and clarity of organizational goals to streamline and optimize system design in an operationally quick manner. There are numerous inter-related decisions to be evaluated in a deepwater development and it is difficult at best for a person or team to fairly weigh all the options and consequences of decisions. The thrust of this effort is to use computational capability to enable virtual system design and operation with measurement of virtual output relative to desired organizational goals. It is envisioned that the interface for this system would be defined and published openly to enable industry to mold their offerings with plug-in capability to the high intensity design engine standard. "The process" was discussed in workshops as holding the key to at least 50 percent of potential savings – the high intensity design system is the attack on this potential area of savings

New System Architecture defines the evaluation process, platform, interfaces, and method of establishing decision rules for a new reservoir development design system.

High Intensity Design Engine defines the actual computational mathematics and mechanics of how components in a system will be optimized and integrated to enable a comprehensive virtual prototype and simulation of output and performance.

Component Optimization Modules are the plug-in modules for specific subsystems such as drilling system, separation, artificial lift, facility sizing, and intervention. A specific set of modules would be targeted first with others to follow as industry desires to become compatible with the new virtual design and optimization standard.

Accelerated Reservoir Exploitation effort challenges the current methods and standards of reservoir exploitation and seeks to increase project value by reducing uncertainty, shrinking time horizons and increasing recovery percentages. Current reservoir exploitation methods are very stepwise and limited due to uncertainties in our knowledge of the subsurface strata and also due in part to the large capital

Table 1A: Ultra-Deepwater Offshore Technology Systems Application Roadmap

		2001	2002	2003	2004	2005	2006
High Intensity Design	**New Systems Architecture**	Definition, Evaluation, and Concept Selection ▼ ◆▲✪+● ❍ ■ ❑	Develop Interface Definition & System Level Decision Rules ▼ ◆▲✪+● ❍ ■ ❑	Publish Open Architecture Definition ▼ ◆▲✪+● ❍ ■ ❑			
	High Intensity Design Engine	Conceptual Flow Sheets & Fast Productivity Index ▼ + ❑	Software to Host System Configuration ▼ + ❑	Develop System Optimization Computational Mathematics & Hardware ▼ + ❑	Comprehensive Virtual System Optimization & Visualization Prototype ▼ + ❑	Pilot Application for Specific Ultra-Deepwater Field Development ▼ + ❑	
	Component Optimization Modules	Critical Components Identification ▼	Virtual Component Module Prototype for 3 Core Subsystems ▼ ◆▲● ❑	Virtual Component Module Prototype for 3 Additional Core Subsystems ▼ ✪ + ❍	Virtual Component Module Prototype for 3 Additional Subsystems ▼ ■ ✶	Virtual Component Module Prototype for 3 Additional Subsystems ✶ ▼ ✪	
Accelerated Reservoir Exploitation	**Reservoir Property Verification**		Low Cost Micro Drilling Self Contained Fluid/Rock Sample Retrieval System ▲● ❍ ◆	Alternative Subsalt Remote Sensing & Imaging Technology ◆ ▲ ✶	Final Reservoir Exploitation Design ▼ ◆ ▲ ● ✶		
	Subsea Gathering Systems	Systems Definition and Early Design ▼ ◆▲● ❍	Low Volume System Lab & Field Trials ▼ ◆▲● ❍	High Capacity System Design and Component Testing ▼ ◆▲● ❍	Offshore Shelf Well Field Trials ▼ ◆▲● ❍	Ultra-Deepwater Field Trials ▼ ◆▲● ❍	
	Reservoir Monitoring and Control	Systems Definition and Early Design ▼ ◆▲	Low Volume System Lab & Field Trials Plus Seismic Fluid Movement Monitoring ▼ ◆▲	High Capacity System Design and Component Testing with Adjustable Learning Completion Capability ▼ ◆▲✪	Offshore Shelf Well Field Trials ▼ ◆▲	Ultra-Deepwater Field Trials ▼ ◆▲	
Rigs/Reach/Riserless	**Riserless Drilling Systems**	Conceptual Engineering and System Architecture ◆ ▲ ✪ ● ❍	Critical Component Development and Testing ◆ ▲ ✪ ● ❍	System Integration and Alpha Testing ◆ ▲ ✪ ● ❍	Shallow Water Trials ◆ ▲ ✪ ● ❍	Deepwater Trials ◆ ▲ ✪ ● ❍	
	System Integration While Drilling	System Concept Development Plus Materials & Placement Research ◆ ▲ ✪ ● ❍	System Architecture Definition & Component Design/Testing ◆ ▲ ✪ ● ❍	System Integration and Alpha Testing ◆ ▲ ✪ ● ❍	Field Trials ◆ ▲ ✪ ● ❍		
	High Capacity Production Wells		System Architecture ◆ ▲ ● ❍	Critical Component Design & Testing ◆ ▲ ● ❍	Field Trials ◆ ▲ ● ❍		
	Intervention Systems	Conceptual Engineering & System Architecture ▼ ◆ ▲ ●	Remote Controlled Light Duty Intervention Robot ▼ ◆ ▲ ●	AUV Service Vessel Intervention Delivery ▼ ◆ ▲ ●	Remote Controlled Micro-Drilling and Workover ▼ ◆ ▲ ●	Fracturing and Cementing AUVs ▼ ◆ ▲ ●	First Time Field Demonstrations ▼ ◆ ▲ ●
Energy to Market	**Subsea Processing & Flow Assurance**	Acoustic Liquefaction, Membrane Separation, & Hydrate Formation/ Transport Research ◆ ▲ ✪ + ■ ❑	Subsea Processing Architecture & Interface Definition ◆ ▲ ✪ + ■ ❑	Critical Component Design & Testing ◆ ▲ ✪ + ■ ❑	System Integration & Testing ◆ ▲ ✪ + ■ ❑	Offshore Shelf Well Field Trails ◆ ▲ ✪ + ■ ❑	Ultra-Deepwater Field Trials ◆ ▲ ✪ + ■ ❑
	Hydrocarbons to Clean Fuel, Feedstock, Products	Research Interface with Clean Fuels Roadmap + ■ ❑ ❈	Conceptual Engineering & System Architecture + ■ ❑ ❈	Critical Component Development and Testing + ■ ❑ ❈	System Integration & Testing + ■ ❑ ❈	Offshore Shelf Well Field Trails + ■ ❑ ❈	Ultra-Deepwater Field Trials + ■ ❑ ❈
	Offshore Power Generation/Transmission	Superconducting Electric Transmission Pipeline Research + ❊ ❈	Superconducting Electric Transmission Pipeline Research + ❊ ❈	Conceptual Engineering & System Architecture + ❊ ❈	Critical Component Development and Testing + ❊ ❈	Critical Component Development and Testing + ❊ ❈	System Integration & Alpha Testing + ❊ ❈
Environmental Management	**Greenhouse Gas Sequestration**	See Greenhouse Gas Sequestration Roadmap					
	Well Control with Near Zero Spill Volume	Sensor Research for Early Detection of Loss of Well Control ▲ ✪ ■	System Development for Point-of-Loss Fluid Capture ▲ ✪ ■	Detailed Design and Model Testing ▲ ✪ ■	Prototype System Testing ▲ ✪ ■	Offshore Shelf Well Field Trials ▲ ✪ ■	Ultra-Deepwater Field Trials ▲ ✪ ■

Table 1B: Ultra-Deepwater New Technology

▼	**Advanced Reservoir Decisionmaking**	deeplook direct reservoir flow variable measurement	advanced semi-analytical methods	new solvers for massive number of equations	geographical corroboration of solution	
◆	**Remote Power Supply Systems**	high capacity transmission methods	downhole fuel cells	ROV / AUV / robotics power	in-situ power generation using native (reservoir) fluids	catalysis techniques for high pressure fuel cells using native fluids
▲	**Subsea/subsurface communications**	reliable wet-connect electrical system	wireless methods	filtering and transmitting acoustic signals for optimum couping	acoustic interbranch communication	
✪	**Materials**	advanced composites	non-metallic materials	new fabrication technology	adjustable property surface coatings	
✚	**Seafloor Chemical Process Engineering**	subsurface adaptation of GTL technology	high pressure fuel cells	micro-reactors for generation of chemicals and fuels	subsea product trains	
●	**Remote Control Drilling**	micro drilling	rig mechanization, modular tool set & robotics	remote mud package	convertible drill mud	reservoir fluid sampling and analysis
❍	**Wellbore Stabilization Methods**	expandable tubulars	casing-while-drilling systems	cementing while drilling	adjustable and reversible pore throat permeability control with cementation	rock fusion
■	**Simultaneous Transport Phenomena**	low-temp solid-liquid equilibria/vapor-liquid equilibria	complex deposition, hydrates, scales, organic solids, & particles	momentum, heat, & mass transfer under general flow conditions		
✷	**Subsalt Imaging**	advanced seismic methods	emerging non-seismic methods			
❑	**Advanced Separations**	compact seafloor / downhole separators	methane permeable membranes for gas upgrading	ceramic membranes	seafloor water conditioning for injection	
❊	**Superconducting Long Distance Transmission**	high capacity bundling	subsea packaging and installation methods	remote underwater splicing technology		
❉	**Carbon Waste Disposal**	new product stream definition and material conversion process	geologic sequestration	waste disposal methods		

commitments required in field development.

Reservoir Property Verification is one of the key hurdles in reducing perceived risk. This effort seeks to address the risks by providing more cost effective methods of collecting direct measurements of the properties in question such as reservoir rock and fluid quality.

Subsea Gathering Systems are a new way of developing reservoirs using underground networks of wells as opposed to individual wells.

Reservoir Monitoring and Contro**l** are critical to understanding and maximizing accelerated desired fluid production from a given reservoir. A multitude of sensing and control mechanisms are envisioned as a part of this initiative.

Rigs/Reach/Riserless

Much of the cost and risk in deepwater and ultra-deepwater reservoir development is related to rig/riser cost and the possibility of not being able to reach the desired reservoir target with a sufficiently sized hole to economically produce the required flow stream. Many of these problems are due to the "scaling–up" of technologies designed for shallower water and land use so they can be applied in ultra-deepwater where loads are higher, lengths are longer, and the environment is more harsh. This effort is intended to apply new technologies in remote operation, sensing , and robotics to change the paradigms of how a well should be drilled and maintained economically in ultra-deepwater.

Riserless Drilling Systems offer the potential of reducing the size and cost of drilling rigs which drive deepwater development costs. Some innovative systems in development today remove conventional risers but still require return lines to surface. This initiative investigates the potential of truly riserless drilling systems.

System Integration While Drilling is a combination of software and tools designed to allow modular construction of the appropriate drainage architecture for a given reservoir on the fly as it is drilled.

High Capacity Production Wells recognizes the high rates to be produced from deepwater wells or networks and addresses some unique concerns such as wellbore stability in drilling, redundancy concepts, and reliability of high rate capable tubulars.

Intervention Systems are critical to increased ultimate recovery percentages. This effort is focused on providing lower cost intervention services and a broader scope of remote intervention capability using robotics, and automated underwater vehicles.

Energy to Market

As reservoir developments move further from shore and into deeper water, infrastructure must be added to get produced fluids, gas or energy/power to market in some fashion. Even when Floating Production Storage and Offloading units are approved for use in the U.S. GOM, there will still be challenges for transporting associated gas. This initiative recognizes the need to solve the full problem including transport of product to market. There are several significant challenges in deepwater – namely flow assurance at cold seafloor temperatures, the high cost of sea surface facility/real estate, and the risks of high rate/high volume loses. In addition, the current pressure toward use of cleaner fuels must be weighed in the decisions of what fuels and products are actually produced and transported.

Subsea Processing and Flow Assurance is an effort to reduce the need for sea surface facilities and cost by placing much of the processing on the seafloor. This will also potentially reduce power requirements by separating unwanted fluids for reinjection without bringing them all the way to the surface and it could solve some flow assurance issues with conditioning of fluids at the seafloor.

Hydrocarbons to Clean Fuel, Feedstock, Products recognizes the need to produce future clean fuels, feedstocks, and products and proposes to produce these as near as possible to the source to avoid non-value adding transport and queueing of fluids at intermediate facilities.

Offshore Power Generation/ Transmission is a recognition of the importance of electricity as a form of power transmission with potentially less threatening environmental consequences of a fault. If electricity can be generated offshore and power efficiently moved to shore while exhaust gases are re-injected to the reservoirs from which they were produced then greenhouse gas emissions may be reduced while also providing increased power availability to U.S. grids. Superconducting cables have the potential to deliver this increased capacity anywhere in the US with little or no losses.

Environmental Management

Environmental issues are crosscutting but are envisioned to require a special focus here due to the potential for significant impact on the environment and project economics. In addition, there should be methods specific to deepwater to control and capture fluids from any loss of well control event. Current methods predominantly attack losses once they reach the surface. In ultra-deepwater we do not want to wait for losses to reach the surface before they are captured. These issues in addition to the many environmental considerations in the other initiatives will need specific focus.

Greenhouse Gas Sequestration: There is a separate technology roadmap for greenhouse gas sequestration and this ultra-deepwater technology roadmap effort should be coordinated with the greenhouse gas effort.

Well Control with Near-Zero Spill Volume is a challenge to develop the needed technology to capture hydrocarbon fluids at the source of a loss event if it occurs in deepwater or ultra-deepwater. Sensors and remote deployment schemes should be developed to capture these fluids while they are still concentrated and before they are dispersed widely to the environment. Deepwater is unique in the sense that the seawater column near the seafloor may be much more hospitable climate for collection of lost fluids than the full water column and broad area rough sea surface.

A metric to evaluate technologies and systems could be utilized to ensure that the impact of technology developments causes market forces to support this effort by directing capital to the ultra-deepwater. This is critical to making the accelerated growth effort sustainable without constant federal government incentives. Other metrics and measures may also be established to ensure environmental stewardship while on this path of accelerated growth.

The Implementation

To expedite technology transfer of vitally needed commercialization of advanced technologies, including ultra-deepwater offshore technologies, the program implementation mechanisms could include the following:

- **Sponsor R&D for technology projects that use an unrestricted array of funding mechanisms** that range from industry-only funded projects to cost-shared arrangements with government that include funding from the mainstream investment sector.

- **A high-level concept development competition for the next generation deepwater architecture.** Several competing revolutionary ideas can be envisaged and proposed by consortia of industry/national laboratories/universities/others. Conceptually, the selected consortia could then be supported in critical mass by federal government to achieve a new open system architecture standard into which all of industry can invest each with its own piece of the technology puzzle; and

- **The Natural Gas and Oil Technology Partnership for technology commercialization collaborations.** The Partnership is an ideal mechanism for transfer of advanced technologies developed either at the national laboratories or through laboratory and industry collaborations. The Partnership is an established, functioning entity. The alliances established through the Partnership combine the resources and experience of the Nation's petroleum industry with the capabilities of the national laboratories to expedite research, development, and demonstration of advanced technologies for improved natural gas and oil recovery. This industry-driven program establishes active industry interfaces through review panels and forums that define industry needs, provide annual project reviews, and determines the priority of new proposals and ongoing projects.

The Department of Energy will create ways to ensure frequent input from stakeholders. This ongoing dialogue will cause the Department to analyze existing mechanisms and identify "best practices" for technology commercialization, identify opportunities for transferring these mechanisms across the Department of Energy complex, streamline the movement of technology exiting the national laboratories, and initiate processes to enhance technology commercialization.

. . . ongoing dialogue will cause the Department of Energy to analyze existing mechanisms and identify "best practices" for technology commercialization, identify opportunities for transferring these mechanisms across the Department complex, streamline the movement of technology exiting the national laboratories, and initiate processes to enhance technology commercialization.

Conclusions

Acceleration of ultra-deepwater development is essential to the future stability and security of U.S. energy supplies. This is a national need and it demands a national effort. Energy is critical to the continued growth of our economy. Steady erosion of U.S. domestic production, while new energy resources are being demanded in significant volumes, leaves the Nation exposed to supply disruptions. By mobilizing the Nation's economic, technical, and natural resources, we can and should develop more environmentally friendly domestic sources of energy. The natural gas and oil will continue to provide about two-thirds of our energy needs over the next 20 years.

. . . the petroleum business has transformed itself into a high-technology industry . . .

Technology improvements are particularly important given the more difficult conditions accompanying new resources.

As addressed by the National Petroleum Council in its 1999 natural gas study, *Meeting the Challenges of the Nation's Growing Natural Gas Demand*, the petroleum business has transformed itself into a high-technology industry in the past three decades (Ref: "Natural Gas: Meeting the Challenges of the Nation's Growing Natural Gas Demand," National Petroleum Council, December 1999). Dramatic advances in technology for exploration, drilling and completion, production, and site restoration have enabled the industry to keep up with the ever-increasing demand for reliable supplies of oil and natural gas while maintaining reasonable prices. The industry is now challenged to continue extending the frontiers of technology. Ongoing advances in E&P productivity and environmental safety are essential if producers are to keep pace with steadily growing demand for oil and gas, both in the U.S. and worldwide.

Technology improvements are particularly important given the more difficult conditions accompanying new resources. Continuing innovation is necessary to sustain the petroleum industry's leadership in the intensely competitive international arena, and to retain high-paying oil and gas industry jobs at home. Progressively cleaner, less intrusive, and more efficient technology will be instrumental in enhancing environmental protection in the future. Reliable and affordable natural gas and oil supplies are critical to sustaining continued growth of the Nation's economy and quality of life.